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PREDICTING THE PAST AND FUTURE IN ELECTRICITY DEMAND

by Duane Chapman, Cornell University
Timothy Mount, Cornell University
Timothy Tyrrell, Oak Ridge National Laboratory

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Department of Agricultural Economics
New York State College of Agriculture
A Statutory College of the State University
Cornell University, Ithaca, New York

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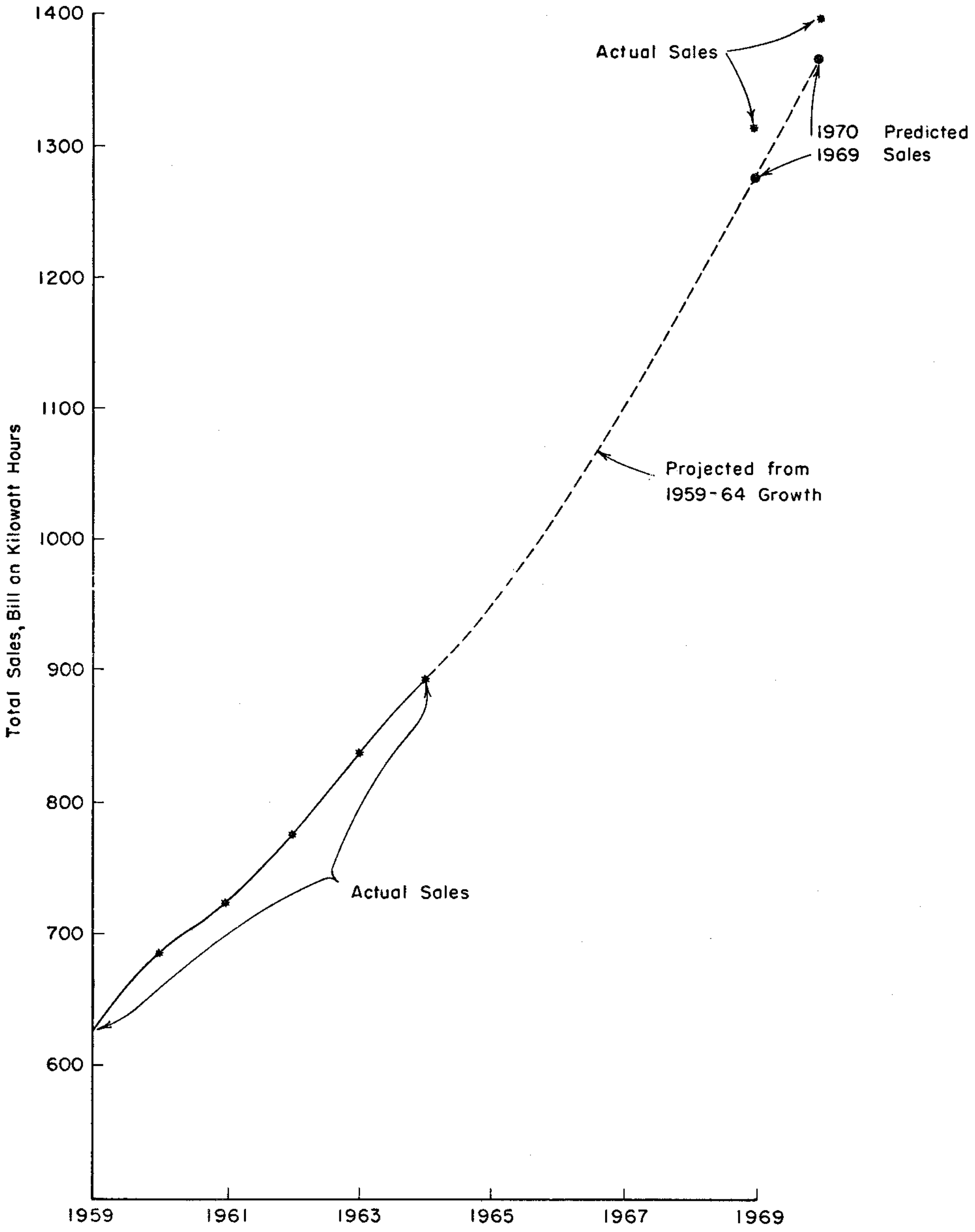
I. Predicting the Past

Consider for a moment a hypothetical analyst working for the Federal Power Commission or the Edison Electric Institute in early 1965. At his morning coffee break he has been asked to project national electricity requirements for 1969 and 1970. He knows his job, and does it in a few minutes. Total sales grew 7.35% per year for the last five years from 1959 to 1964. So he predicts total sales will grow 7.35% per year for the next five years to 1.28 trillion kilowatt hours in 1969 and to 1.37 trillion kilowatt hours in 1970. For good measure he draws the graph in Figure 1 before leaving for lunch (omitting, of course, the actual sales for 1969 and 1970).

Seven years pass, a time of war and rebellion, inflation and unemployment, increasing affluence and hardening poverty. In early 1972 he recalls that prediction, and decides to check it against actual sales as reported in the Statistical Year Book.1/ Actual sales were 1.31 trillion kilowatt hours in 1969 and 1.39 in 1970. Our analyst calls a friend in his local utility to meet him for lunch, and together they note with enthusiasm the accuracy of their methods. They discuss the views held by some economists that rising environmental protection costs will change the pattern of growth. But they note the recent coexistence of recession and rapid inflation (which economists believed to be mutually exclusive), and conclude that economists could learn something from them about prediction. Total sales, they agree, will grow to 11.82 trillion KWH in 2000.

Perhaps this suggests a useful criterion for judging the value of economic analysis: can projection based upon more complicated assumptions give more accurate results than extrapolation?

FIGURE I. PREDICTING THE FUTURE FROM THE PAST



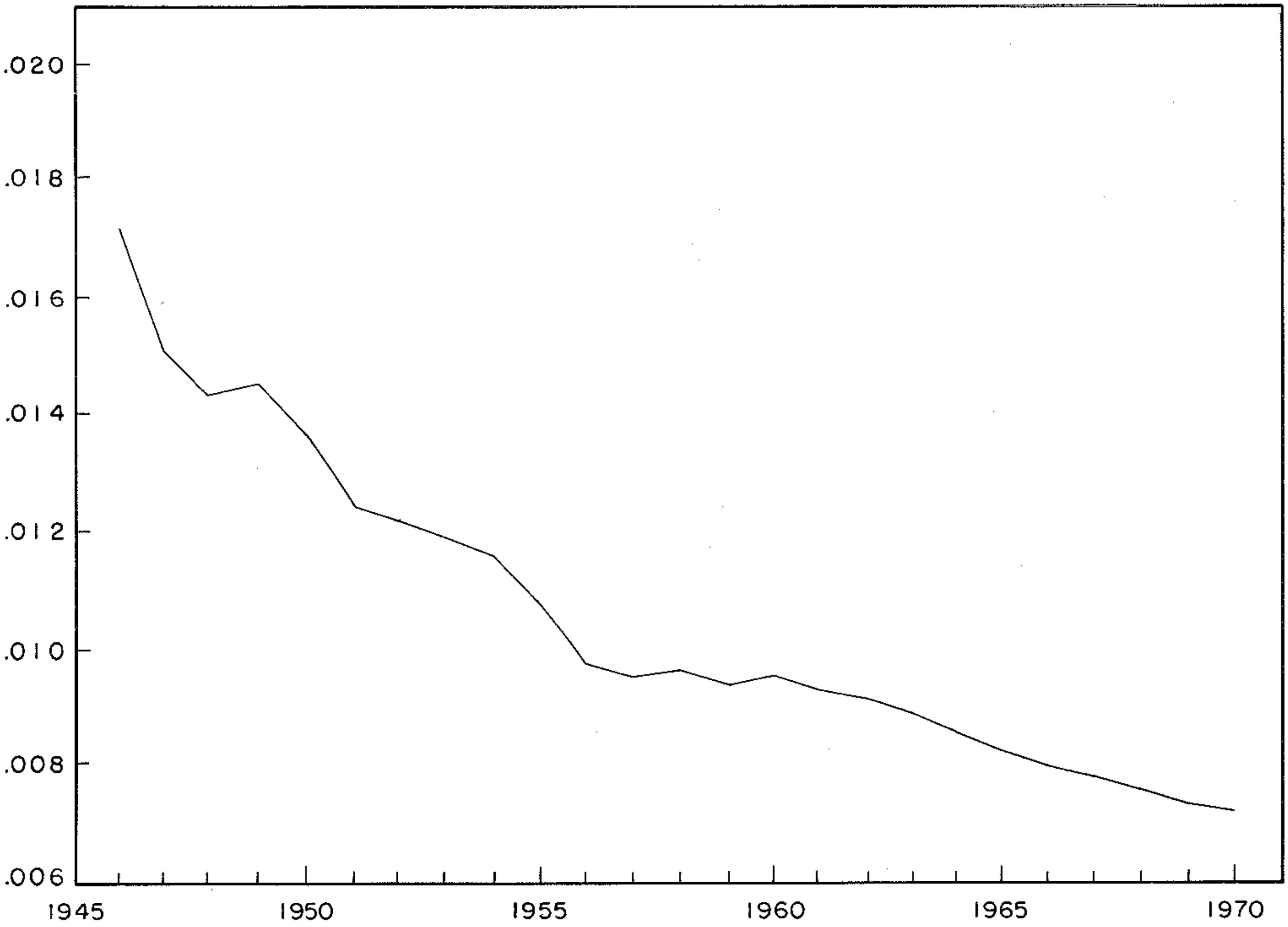
In fact, the economic history of the post-war era indicates all causal factors influencing electricity demand have themselves changed quite predictably, and these changes have all pointed towards regularly increasing demand. As we shall see, this pattern will break in the near future (if indeed it has not already), and it seems unlikely that electricity demand will behave as nicely in the future as it has in the past.

First, we note that population and disposable personal income have increased regularly since the war, and these are important positive influences upon the purchase and utilization of appliances and lighting. For business and industry, value added or gross national product would probably be a more relevant income variable, and we note that here too there has been a nearly continuous increase since the war.

In addition, the average prices that consumers, business, and industry have paid for electricity have fallen since the war, and this has happened while most prices were increasing.

When we consider the past relationships between electricity prices and the prices of competitive goods, we see that electricity has become an increasingly better buy since WW II. Figure 2, for example, shows how average industrial electricity price has declined relative to capital costs as measured by the price index for nonresidential fixed investment. This picture is equally true for other factors. The average industrial and commercial electricity prices have fallen relative to unit labor costs, natural gas prices, total energy prices, and overall wholesale prices. The average residential electricity price has declined relative to overall consumer prices, natural gas prices, and fuel oil and coal prices. (These patterns are shown in the appendix.) All of these ten relationships have changed in a generally smooth manner, and all of them are causal factors in increasing electricity use.

FIGURE 2. RATIO OF THE AVERAGE INDUSTRIAL ELECTRICITY PRICE TO THE IMPLICIT GNP PRICE DEFLATOR, NONRESIDENTIAL, FIXED INVESTMENT



The influence of the prices of complementary goods is the same. The cost of electrical machinery for business has declined relative to overall wholesale prices since 1959, and the cost of household appliances has declined relative to overall prices since 1945.

To summarize, population, income, electricity prices, the prices of goods competitive to electricity, and the prices of appliances and machinery using electricity have all changed in directions which result in greater electricity demand, and each of these changes has been generally smooth.

Further, this pattern is essentially the same for all areas of the country for all consumer classes for the entire period since WW II.

The electric utility industry is to be credited for meeting our expectations. We have had accelerating consumption at a nearly constant exponential rate, a generally firm supply, and declining prices.

However, it seems likely that the factors causing this past growth are in the process of rapid change, and in the near future we are likely to see these factors pointing in different directions and changing at different rates than they have in the past.

If this divergence of causal factors from past patterns does in fact occur, it seems clear that electricity demand growth will depart from past patterns.

Other participants in this panel will address themselves to the likely consequences of changes in electricity growth. We shall only note here that the primary effects would seem to be a reduction in the growth of consumption of metal products (including cars), plastics, chemicals, drugs, petroleum and gasoline, man-made fibers, and cardboard and paper products.[2/]

In residential use, retardation in demand growth would probably affect growth in air conditioning, electric ranges and heating, lighting, clothes dryers, and possibly electronic appliances.

Three forces are likely to modify future demand growth. They are (1) noticeably increased cost of environmental protection for one or more stages of the generating process for each method of generation, (2) possible reduction in the growth rate of population, (3) possible reduction in the growth rate of per capita income.

In the next section we review past and current research on electricity demand to determine the likely values and reliability of quantitative estimates of these different influences and the time path of response of electricity demand to changes in these factors.

The last section analyzes various administrative, legislative, and social policies in the context of available information on their likely consequences.

II. Quantitative Analyses of the Factors Influencing Electricity Demand: An Appraisal.

In the previous section, five different factors are assumed to be responsible for the growth of the quantity of electricity consumed. These factors are population, income, the prices of electricity, prices of competitive goods such as substitute fuels, and prices of complementary goods such as electrical appliances. Although the directions (positive or negative) of the relationships between each of these variables and demand can be described from economic theory, the relative importance of each factor can not be determined. The major objective of most quantitative analyses of electricity demand is to estimate a magnitude for each relationship. These estimates can then be used to predict the impact of a specific policy change on the quantity of electricity demanded. For example, suitable estimates would provide a guide to answering the following questions. Will the reduction in electricity demand be large or small if a tax on sulphur emissions results in a five percent increase of electricity prices, or if income per capita increases by six percent instead of three percent annually?

In most economic applications, the magnitude of the relationship between a variable and demand is measured as an elasticity.[3] Hence, one objective in a quantitative analysis is to determine accurate estimates for the elasticities of each variable. This is not necessarily a simple task. In many situations, severe limitations exist in the quality of available data, and consequently, in the reliability of standard statistical methods. A more detailed discussion of these limitations and their consequences follows. In addition, an appraisal is given of certain procedures that have been used regularly in quantitative studies to offset these limitations.

The first choice that has to be made in any quantitative study of demand concerns the mathematical form of the demand function. This decision generally reflects a compromise between mathematical simplicity and the true demand relationship. As multiple regression techniques are convenient to use and as economists are interested in estimating elasticities, the linear regression model with all variables transformed to logarithms has been widely adopted. However, the suitability of any model must be judged in terms of performance. Are the estimated elasticities accurate and consistent with economic theory? Does the model provide an adequate approximation to the data? Can reliable predictions be made when new data are available?

The second consideration is to decide on exact specifications for the variables in the model. The different factors that should be included are generally determined from economic theory, and in our analysis, the demand for electricity is assumed to depend on five explanatory variables. The more detailed choices concerning measurement procedure are not as clearly defined. For example, should price and income variables be in real or money units? This type of decision can only be judged by performance.

One measurement problem that has more serious implications for the demand model concerns the price of electricity. The simplest measurement procedure is to calculate the average price by dividing revenue by quantity. As an alternative, the practice of charging lower prices to large users (decreasing block rates) has encouraged some analysts to attempt to measure the marginal price from "Typical Electric Bills" published by the Federal Power Commission. In single equation models with quantity demanded as the dependent variable, price is assumed fixed. However, if price changes whenever the quantity changes, price and quantity should be determined simultaneously in the model, and single equation procedures are no longer valid. There are a number of reasons why simultaneity is not a serious problem in electricity demand. Firstly, "block" pricing implies that marginal prices for each block are fixed over a specified quantity range. Secondly, these quantity ranges are chosen by utility companies to distinguish between different classes of consumers. Hence, if demand functions are estimated separately for each consumer class, the single equation model is appropriate. Finally, utilities use a pricing formula to determine the price for each consumer class. This type of procedure is not consistent with standard market models in which price and quantity are determined simultaneously. It is reasonable to conclude that the choice between using average or marginal price should be made on the basis of performance.

Many analysts have estimated demand elasticities for individual states using time-series data. However, as was shown in the last section, all the relevant variables have trended over time, and consequently, are highly intercorrelated (multicollinear). This limitation of the data makes the estimation of individual elasticities very inaccurate. It should be noted that prediction of the quantity demanded may still be reliable even though individual estimated regression coefficients are not. Nevertheless, accurate estimates of the elasticities are required if different policy options are to be compared. Some analysts assume that a variable is unimportant if its coefficient is not significantly different from zero. In spite of this, if the estimated error of the coefficient is large as it tends to be with multicollinear data, then this lack of significance reflects the inaccuracy of estimation and does not imply that the variables can be omitted from further consideration.

A variety of procedures can be used to counteract the problems of using multicollinear data. For example, the number of explanatary variables can be reduced, but two different situations should be distinguished. A variable such as population can be dropped if all quantity variables are expressed on a per capita basis. This is equivalent to imposing certain restrictions on the model that are in many situations quite plausible. In contrast, variables can be dropped with no adjustment of the remaining variables. However, this procedure is not recommended even though estimated coefficients appear to be more accurate. Omission of relevant variables from a regression model implies that all estimated coefficients are unreliable (biased and inconsistent). Hence, if the price of gas influences electricity demand and this variable is omitted, the estimated coefficients for the other variables "include" the gas price effect. In some studies, serial correlation of the residuals appears to be an additional estimation problem, but this serial correlation may be caused by the omission of variables. It is preferable to remove the problem by including all relevant variables rather than to "correct" the residuals for serial correlation.

A more promising approach is to reduce the multicollinearity by changing the data base, and the simplest way is to use cross-section data. However, the inevitable lack of homogeneity between units of the cross section is often ignored, implying that estimated coefficients are once again unreliable (biased). In addition, most policy considerations are related to changes through time, and there is no reason to expect that estimated cross-section elasticities are suitable for making predictions about changes over time.

The obvious next step is to pool both cross-section and time series data. The pooling is expected to reduce multicollinearity to a manageable level. Heterogeneity between units of the cross section can be accounted for by making each elasticity itself a function of certain measurable variables.[4/] Such a model could still be handled in a multiple regression framework, and would provide estimates of all elasticities specifically for each cross sectional unit (e.g., state). In addition, the serious misspecifications of omitting relevant variables and ignoring heterogeneity are avoided.

A further consideration that should be discussed concerns the adjustment path through time of the quantity of electricity to changes in the explanatary variables. As electricity consumption is related to the stocks of electrical machinery and appliances, and the sizes of these stocks reflect past as well as current decisions, the current quantity of electricity demanded is also related to past as well as current values of the explanatary variables. This type of situation is familiar to economists and can be incorporated into a linear regression framework using a distributed lag model. Ignoring the lag structure is equivalent to omitting relevant variables, and consequently, estimated coefficients are unreliable (biased and inconsistent).

The most widely used distributed lag model specifies that the lag structure declined geometrically over time. With this model, it is possible to estimate both the short run elasticity (the response that occurs in a single time period) and the long run elasticity (the response after the adjustment process is completed). However, in most empirical applications, a lagged dependent variable (the quantity of electricity demanded in the preceeding time period) is used as an explanatory variable. As this procedure tends to aggravate the problem of multicollinearity, the need for using pooled cross-section and time-series data is even greater. Relatively few studies of electricity demand consider the distributed lag model.

Anyone who makes a casual survey of the different quantitative studies of electricity demand will probably be disconcerted by the wide range of estimated elasticities. However, many of the apparent inconsistencies between studies can be traced to misspecifications in the models that are estimated. Although it is generally not possible to measure the impact of a particular misspecification on each elasticity, it is unnecessary to rely on estimates from models that are clearly misspecified unless no alternative estimates are available. In Table 1 the six best known studies of the demand for electricity are summarized.5/ It appears from this summary that there is still a need for more accurate estimates.

Table 2 summarizes our view of likely short run and long run elasticities for selected major factors. These estimates are based upon our own work6/ and that noted in Table 1. Given the difficulties in analysis discussed here, making such estimates is clearly a risky affair at present. The reader is given fair warning: Table 2 will be substantially revised in its final version. We have more confidence in the price, population, and long run estimates, and less confidence in the income, fossil fuel price, and short run estimates.

Table 1. Summary of Recent Studies of Electricity Demand

Authors	Date of Study	Class of Demand	Type of Data	Variables Included[1/] P_E	Y	N	P_F	T	Others	Type of Model
1. Fisher and Kaysen	1962	Residential	Annual time series for each of 47 US states. (1946-57)	X	X	2/		X		First difference of logarithmic variables
2. Baxter and Rees	1968	Industrial	Quarterly time series for industries in UK. (1954-1964)	X			X		Industrial output, Temperature index	Geometric lag model with logarithmic variables
3. MacAvcy	1969	All classes	Pooled quadrennial time series for 9 regions in US (1958-1972)	X	X	X				Logarithmic variables
4. Wilson	1971	Residential	Cross section of 77 cities in US (196?)	X	X	2/	X		Housing unit size, Temperature index	Linear and logarithmic variables
5. Halvorsen	1971	Residential	Pooled annual time series for 47 states in US (1961-69)	X	X	2/	X		Temperature index, urbanization index	Simultaneous models with alternative forms of the demand functions
6. Anderson	1972	Residential	Cross section of 47 states in US (1969)	X	X	X	X		Temperature index, urbanization index	Lag model using logarithmic variables on a per household basis

1/ P_E = Price of Electricity, Y = Income, N = Population, P_F = Price of Alternative Fuel, T = Trend, Price of Appliances not included in any study.

2/ Quantity variables specified on a per capita basis.

Table 2. Summary of Electricity Price, Income, Population, and Fossil Fuel Price Elasticity Estimates

	Long Run	Short Run	Income Influences	Price Influences
Electricity Price				
Residential	-1.1	-0.1	Rising Income Lowers Price Elasticities	Rising Price Raises Price Elasticities
Commercial	-1.3	-0.2		
Industrial	-1.5	-0.3		
Income	+ .6	+ .08	Rising Income Lowers Income Elasticities	Rising Price Lowers Income Elasticities
Population	+ .9	+ .1		
Fossil Fuel Price	+ .1	+ .01		

III. Implications for Legislative, Administrative, and Social Policy

A. Internalizing Externalities.

This phrase is usually used in the sense that Federal and State legislation and administrative policies should cause private and public organizations to eliminate or reduce their actions which cause environmental degradation. The costs of such environmental protection are expected to be financed out of higher prices, appropriations, or profits. For electricity generation, the important types of environmental degradation are well known. The nature and extent of the damage from such activities is in general not well understood. Similarly, the costs of eliminating or reducing these effects are known with varying degrees of reliability.

Given the estimates of price elasticities summarized in the preceding section, it is apparent that substantial "internalization of externalities" will in turn cause reduction in future growth. Analyzing this impact can proceed in various ways. We may consider general cost increases or the cost of specific protection activities; we may attempt to analyze consequences on an aggregate national basis, or we can work with specific geographic areas.

Since the summer of 1970 the major purpose of our research has been to develop quantitative estimates of demand response to environmental protection policies, and we are now in a position to undertake the examination of demand response to externality internalization. In one study, we have explored the response of electricity demand in New York in each of the major classes to the increased costs that would follow the implementation of a Federal sulphur emission tax.[7/] In some ways this is more difficult than an examination of general cost increases. It was desirable to work with 39 economic and engineering variables over a twenty year period. The results for the projections for 1990 for New York are of some interest, and are shown in Table 3.

Some surprises are evident. First, as expected, a tax high enough to motivate control causes a reduction in sulphur emissions and damage. But unexpectedly the tax-induced cost would have no noticeable impact on electricity demand growth. Consequently, given the assumptions of proportional capacity growth used in the paper, 21 new nuclear power plants of 1000 MWe capacity -- or their equivalent -- would be required with or without a sulphur tax.

In a qualitative sense the results of the New York study are applicable to the nation: it seems unlikely that the imposition of a sulphur emission tax in and of itself would have a visible impact on electricity growth. In this case "internalizing the externality" markedly reduces the externality and its damage, but does not modify demand growth.

The second study began from a different point of view.[8/] We postulated different sets of assumptions for the Nation about future (1) environmental protection costs in electricity generation, (2) population growth, (3) income growth. Then, given the type of quantitative estimates in Table 2, we examined how electricity demand growth would be modified by different possible patterns of these factors. Now internalization becomes an important modifier of demand growth. Let us take as a "baseline" projection the moderate price decline case. Here, as in the five other cases reported in Table 4, population and per capita income continue to grow at past annual rates of 1.3% and 3.0% respectively. The change in direction in cost pattern in Cases D, E, and F show significant reductions in demand growth. Similarly, if prices

Table 3. 1990 Projections for New York without and with a Federal Sulphur Tax

	Case A No Sulphur Tax	Case B Sulphur Tax
Generation, billion KWH		
Total	276.9	271.9
Coal	32.5	32.5
Oil	49.2	48.5
Nuclear	153.5	149.4
New Generation, billion KWH		
Total	181.5	176.5
Oil	24.9	24.2
Nuclear	149.2	145.1
New nuclear plants, 1000 MW	21	21
Sulphur, million tons		
In coal and oil	.271	.269
Proportion emitted	1.000	.100
Sulphur emitted	.271	.027
Damages, tax, control costs, million dollars/year		
Damage to New York	$157	$ 16
Change in damage	0	-141
Tax	0	5.4
Control cost	0	64.0
Damage plus control cost	157	80
Tax plus control cost	0	69.4
Tax plus control cost, cents/KWH	0	.026
1970 average price plus tax and control cost, cents/KWH	1.97	2.00

Source: See text.

should fall rapidly over the rest of the century, demand growth may accelerate.

In summary, we can conclude that internalizing some specific costs such as sulphur removal may not noticeably affect demand growth, while a general policy of internalization may result in substantial modification of demand growth.

B. Efficient Environmental Protection Now Means Fewer Future Problems.

This is essentially a restatement of the preceding discussion from a different perspective. It means that effective regulation of airborne emissions, strip mining, oil spills, heat discharge, radioactive material disposal, etc. will reduce the scale of future problems by reducing the growth rate of demand and the need for new plants and capacity.

C. Extrapolation of Past Growth will be Inaccurate

In the first section it was noted that more accurate prediction than is possible with extrapolation should be a criterion for judging the efficiency of quantitative analysis of the factors influencing demand. It is clear to us that -- in the absence of major new technological developments such as electric cars or nearly costless fusion power -- increasing environmental protection costs will reduce the growth of electricity.

D. The Environmental Significance of Inverted Peak Demand Rates

There is much confusion surrounding this subject, and it is justified. Rate structures in most states will, at a given time of day or year, generally charge large users less per average KWH than small users. The last KWH will generally cost less than the average KWH. These characteristics have developed in response to a variety of economic influences. The more important of these influences are (1) economies

Table 4. Effects of Internalized Environmental Protection Cost on Demand Growth

	Prices			Total[a] Generation trillion KWH
	Residential	Commercial	Industrial	
A. 1970 Levels	2.10¢/KWH	2.01¢/KWH	0.95¢/KWH	1.5
B. Moderate Price Decline				
1. Rate of change	-2.1%/yr.	-2.3%/yr.	-1.4%/yr.	
2. 2000 levels	1.11¢/KWH	1.00¢/KWH	0.62¢/KWH	11.5
C. Decline at Past Rate				
1. Rate of change	-4.2%/yr.	-4.6%/yr.	-2.8%/yr.	
2. 2000 levels	0.58¢/KWH	0.48¢/KWH	0.40¢/KWH	35.9
D. Level at 1970 Value				
1. Rate of change	0	0	0	
2. 2000 levels	2.10¢/KWH	2.01¢/KWH	0.95¢/KWH	4.0
E. Moderate Price Increase				
1. Rate of change	+4.2 mills/ KWH/yr.	+4.0 mills/ KWH/yr.	+1.9 mills/ KWH/yr.	
2. 2000 levels	3.36¢/KWH	3.22¢/KWH	1.52¢/KWH	1.7
F. Rapid Price Increase				
1. Rate of change	+10.5 mills/ KWH/yr.	+10.1 mills/ KWH/yr.	+4.75 mills/ KWH/yr.	
2. 2000 levels	5.25¢/KWH	5.03¢/KWH	2.38¢/KWH	0.7

[a] Including other uses and losses

of scale resulting in lower average cost for higher levels of generation and transmission, (2) the fair rate of return principle influencing profit and therefore rates, (3) joint costs of production are substantial, (4) load levelling with lower night rates is common, (5) very large users can negotiate rates with a utility, (6) most public and private utilities and the regulatory agencies expect efficient management to produce and sell electricity at minimum cost.

Inverted peak demand rates are connected to environmental protection in two ways. First, peak load units, whether pumped storage capacity or small fossil plants, seem to have a higher than average environmental cost per KWH. Second, in some areas environmental controversy surrounding new plant sites has restricted capacity growth, thereby increasing the peak demand capacity problem. Advocates of inverted peak demand rates see this as a partial solution to both problems. Higher rates for higher levels of use are expected to reduce the need for new plants by load levelling. These rates are expected to reduce air pollution from existing fossil peak capacity units. Finally, inverted rates are expected to reduce the peak load stress on system capability, thereby decreasing brownouts and voltage reductions.

The research described here indicates that peak demand would decline if peak demand rates were increased. The viability of this policy as a solution to short run problems must be qualified by the delayed nature of response as discussed below.

E. Social Policy: Population and Income Growth

It would be folly to suggest that electricity demand dictates population and income decisions, but the reverse relationship has been and will be important. Although electricity demand has grown much more rapidly than population or per capita income (and much faster than the product of the two), Table 2 indicates that these factors will influence future electricity growth. It is unlikely that ZPG and ZEG will commence today but it is possible that future growth in both population and income will be less than it has been since WW II.

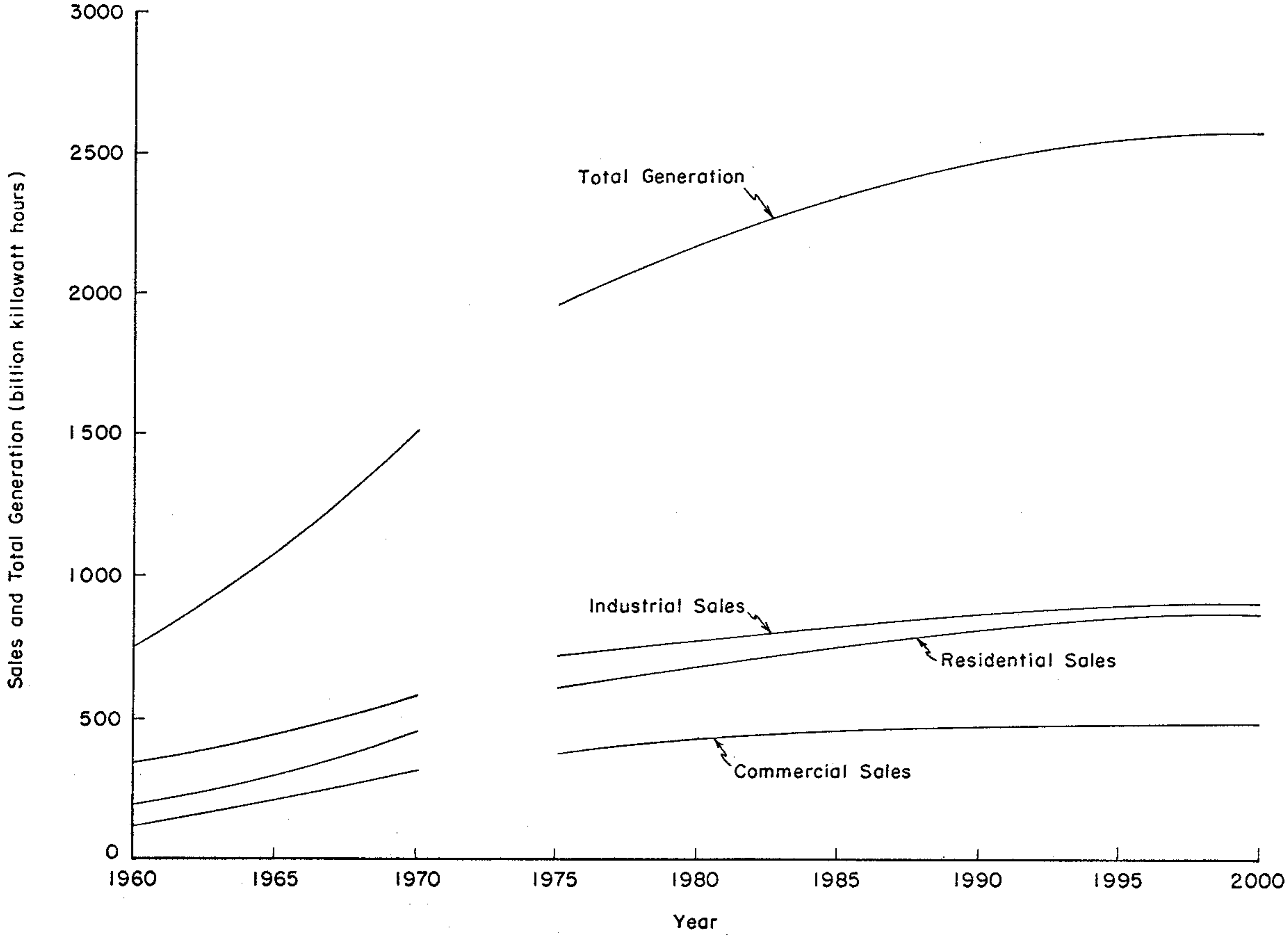
One of our projections in the national study discussed above assumed that population growth would begin this decade at its past growth rate of 1.3%, but slowly fall year by year until zero growth occurred from 1999 to 2000. A similar assumption was made with real per capita income, so it rose 3% this year, but the growth rate slowly declined until zero growth occurred in 1999-2000. We added to these "ZPG 2000" and "ZEG 2000" assumptions an environmental protection policy such that electricity prices would no longer decline relative to other prices. This means that future savings in efficiency and returns to scale are assumed to be used to purchase growing environmental protection.

The result is shown in Figure 3. Note that sales to each consumer class as well as total generation grow at past rates in the near future, but stabilize at the end of the century, well below 11.5 trillion KWH generation.

F. The Timing of Demand Response to Modifying Factors

As observed in the preceding sections, there is good reason to expect that for all consumer classes electricity demand is influenced by the purchase of electricity using appliances, machinery and equipment, and by the rate of use of those appliances. Electricity prices, population, income, competitive fuel prices, electrical machinery prices, and prices of machinery competitive with electrical machinery all influence the purchase of such equipment. Therefore we expect a lagged response in elec-

Figure 3: Zero Population and Income Growth Reached in 2000, 1970 Prices Maintained



tricity demand to changes in these factors. Each of the types of demand response discussed in this section should be envisioned as having a small but perceptible influence in the year of (or the first year following) the change in the causal factor. We are as yet uncertain of the length of time necessary for most of the full cumulative response to occur; a range of 3 to 10 years is the best estimate that can be offered today.

G. A Final Caution and a Conclusion

We must emphasize the preliminary nature of the numerical results discussed here. It is likely that some of these estimates will be substantially revised in the next few years. Nevertheless, there is sufficient information available to conclude that future electricity demand is not deus ex machina, but the sum of predictable responses to many separable choices.

FOOTNOTES AND REFERENCES

1. Edison Electric Institute, *Statistical Year Book of the Electric Utility Industry*, annual.
2. Based upon G. C. Gambs and A. A. Rauth, "The Energy Crisis," *Chemical Engineering*, May 31, 1971, pp. 56-68; K. P. Anderson, "The Demand for Electricity in California -- Dimensions of Future Growth," WN-7550-NSF, Rand Corp., Santa Monica, Aug. 1971; and O. Culberson, "The Consumption of Electricity in the United States," ORNL-NSF-EP-5, Oak Ridge National Laboratory, June 1971.
3. The demand elasticity is defined as the percentage change of the quantity demanded in response to a one percent increase of an explanatary variable such as price. For example, a price elasticity of -1.5 implies that a 1% increase of price reduces the quantity demanded by 1.5%.
4. It should be emphasized that standard analyses of covariance models for pooling data specify that elasticities are identical for all cross-sectional units as only the intercepts are different.
5. 1) F. M. Fisher and C. Kaysen. *The Demand for Electricity in the United States.* North Holland, Amsterdam, 1962.

   2) R. E. Baxter and R. Rees. Analysis of the Industrial Demand for Electricity. *Economic Journal* *78*, 1968, pp. 277-298.

   3) P. W. MacAvoy. *Economic Strategy for Developing Nuclear Breeder Reactors.* M.I.T. Press, Cambridge, Mass., 1969.

   4) J. W. Wilson. Residential Demand for Electricity. *Quarterly Review of Economics and Business* *11*, 1971, pp. 7-22.

   5) R. Halvorsen. *Residential Electricity: Demand and Supply.* Paper presented to the Sierra Club Conference on Power and Public Policy, Johnson City, Vermont, Jan. 14-15, 1972.

6) K. P. Anderson. The Demand for Electricity: Econometric Estimates for California and the United States. RAND, Santa Monica, Calif. R-905-NSF, 1972.

6. The study is working with data from 1946-70 for each state and region for residential, commercial, and industrial users. Various functional forms, variables, and dynamic models have been examined. Results should be published in 1972.

7. D. Chapman, T. J. Tyrrell, and T. Mount, "Electricity and the Environment: Economic Aspects of Interdisciplinary Problem Solving," presented at the American Association for the Advancement for Science meeting, Philadelphia, Dec. 26-31, 1971.

8. D. Chapman and T. Tyrrell, "Alternative Assumptions about Life Style, Population, and Income Growth: Implications for Power Generation and Environmental Quality," presented at the Sierra Club Conference on Power and Public Policy, Johnson City, Vermont, Jan. 14-15, 1972.

APPENDIX

The sources for the data for Figures 1 and 2 in the text and the following graphs are *Statistical Year Book* of the Edison Electric Institute, *Business Statistics*, *Survey of Current Business*, *National Income and Product Accounts of the United States*, *1971 Economic Report of the President*, *Gas Facts*, *Monthly Labor Review*, and telephone communications with the Federal Power Commission and Edison Electric Institute.

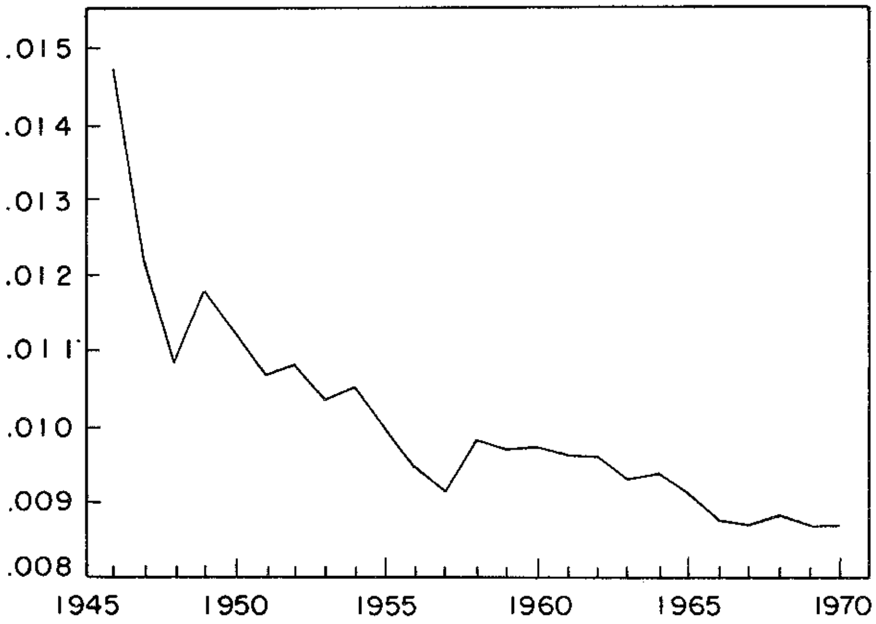


Fig. A1. Ratio of the average industrial electricity price to the total fuel and power wholesale price index.

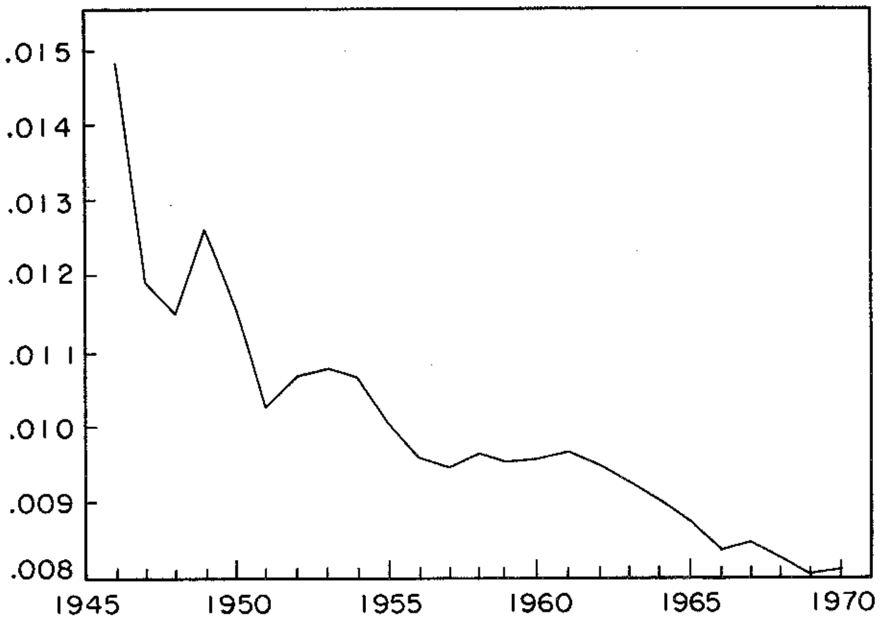


Fig. A2. Ratio of the average industrial electricity price to the all commodity wholesale price index

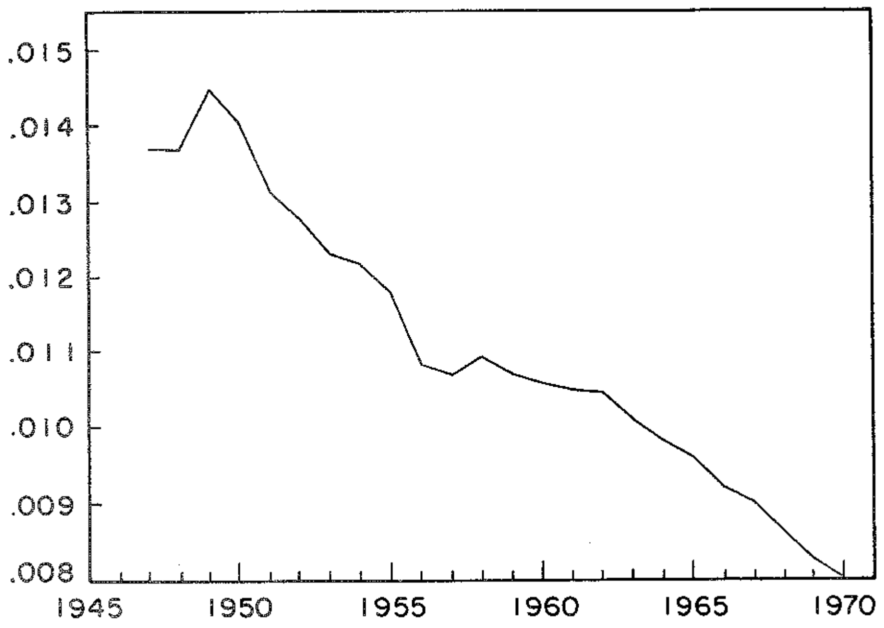


Fig. A3. Ratio of the average industrial electricity price to the unit labor cost.

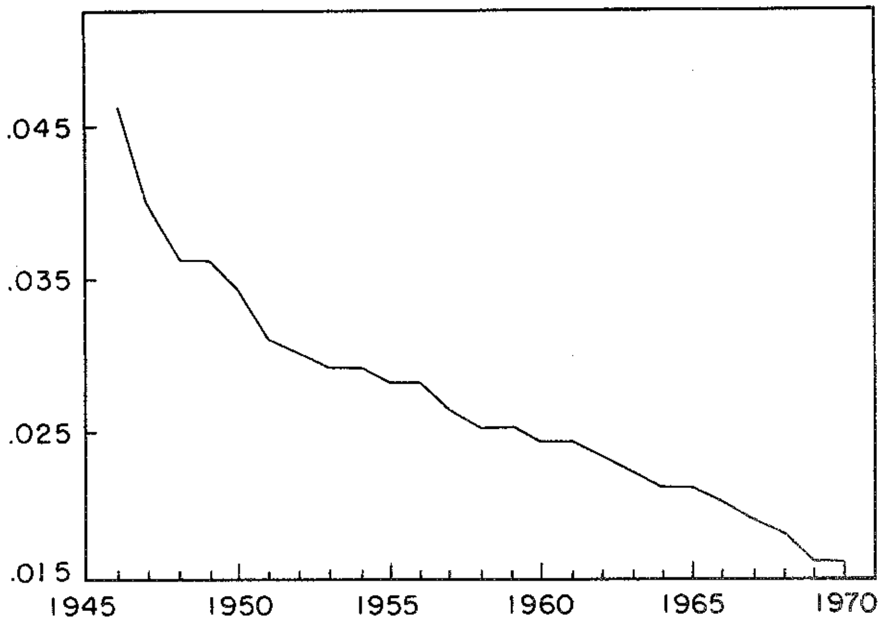


Fig. A4. Ratio of the average residential electricity price to the consumer price index.

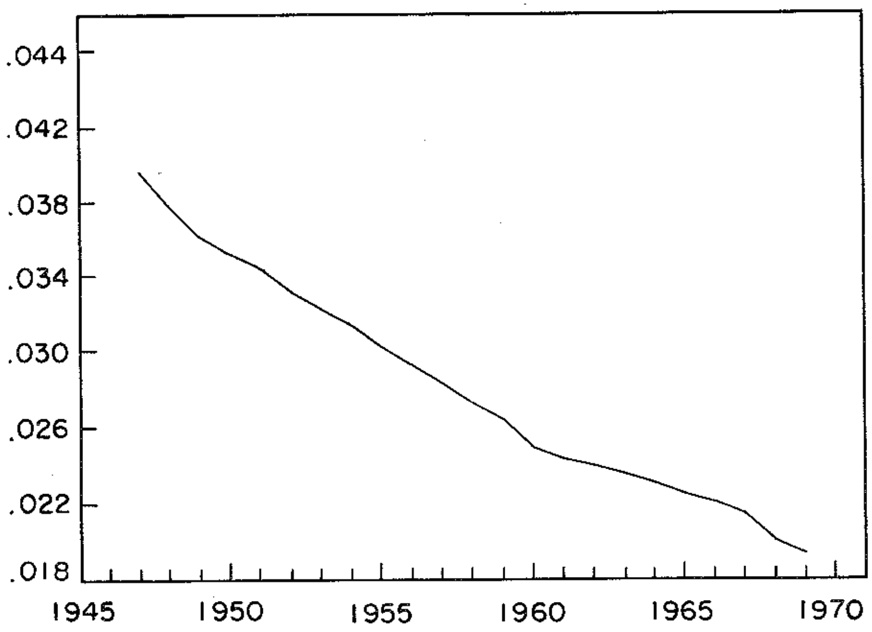


Fig. A5. Ratio of the average residential electricity price to the gas consumer price index.

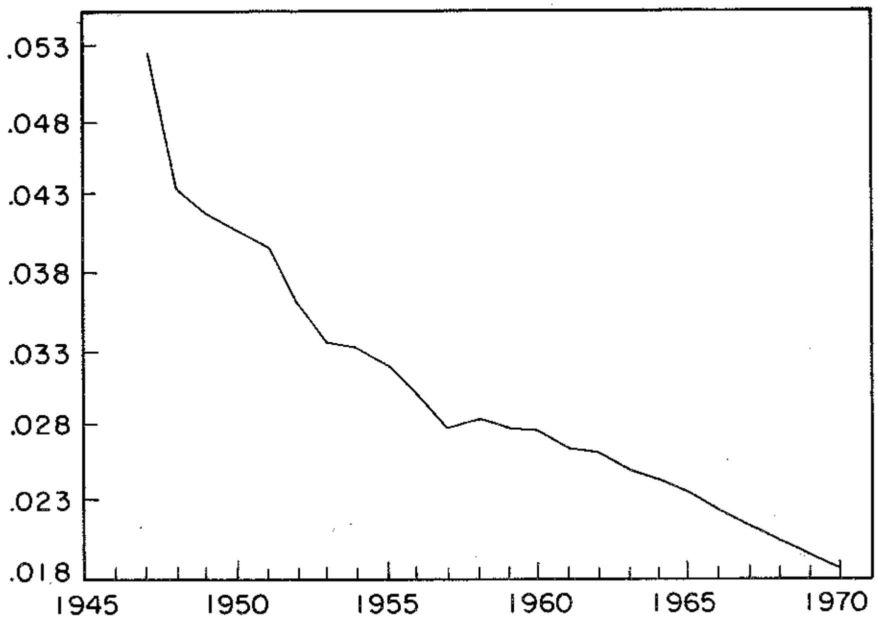


Fig. A6. Ratio of the average residential electricity price to the fuel oil and coal consumer price index.

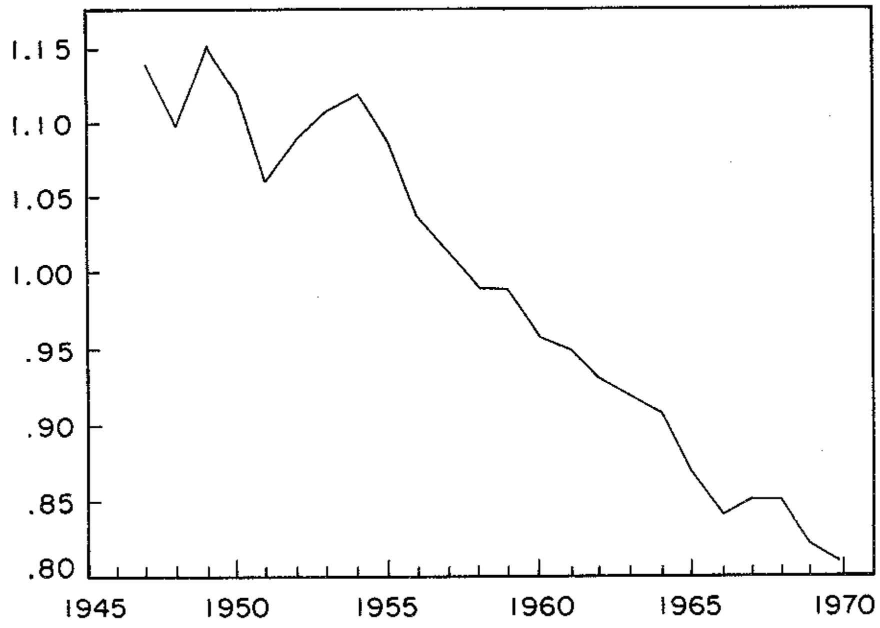


Fig. A7. Ratio of the household appliance wholesale price index to the all commodity wholesale price index.

January 1974

"Predicting the Past and Future in Electricity Demand" is no longer available but there are three other articles that are offspring of this early work and contain more recent and updated information:

"Electricity Demand Growth and the Energy Crisis,"
"A Sulfur Emission Tax and the Electric Utility Industry," and
Electricity Demand in the United States: an Econometric Analysis.

If you are interested in any of these, please write

Duane Chapman
304 Warren Hall
Cornell University
Ithaca, N. Y. 14850

Sincerely

JM Ostrofer
J. M. Ostr

Duane Chapman